been thought worth while to bring the co-ordinates past the epoch 1880.

Commencing astronomical observations in 1861 with a very small instrument, Prof. Burnham obtained a six-inch equatorial from Alvan Clark in 1869, with which he commenced systematic work on double stars in 1872. Since that time his observations have been made with instruments of varying aperture, 9·4, 12, 15·5, 16, 18·5, 26, 36 and 40 inches respectively.

Especially interesting is the fact that a great proportion of the pairs discovered have been found to be physically binary, and that these are generally closer and more difficult to measure compared with those in slower motion.

A special list of quadruple stars is given, and various measures have been obtained by the co-operation of other observers with different instrumental equipment. The stars are arranged in order of right ascension; and besides the present elements, a short description of special particulars with comparative previous measures are added to each where necessary, and several illustrations are given of the instruments used in the course of the work.

SOME RESULTS OBTAINED WITH A STORAGE BATTERY OF TWENTY THOUSAND CELLS.[1]

THE remarkable development of practical employments of electricity have put the professor of physics at a disadvantage, compared with the electrical engineer. The latter has at his service thousands of electrical horse-power, while the college instructor can barely obtain fifty. The engineer can experiment with enormously strong currents and study their effects in chemical industries, and in the production of intense heat. Thus the study of the manifestations of electricity on a great scale seems to be relegated to the electrical engineer.

There is one direction, however, in which the university professor can enter into competition with the engineer and even surpass him in resources. This direction is in the field of high electromotive force; and I wish to call your attention to some results which I have obtained with a storage battery of twenty thousand cells. For several years I have had at my command ten thousand cells; and the plant has proved so practical that I resolved last autumn to double the number of cells. The battery is now finished, and you will have an opportunity of seeing its manifestations.

With twenty thousand cells of the Plante type I can obtain forty-two thousand volts, and by the use of Leyden jars I can step up to three million. I cannot go higher, for the very interesting reason that air at atmospheric pressure becomes a fairly good conductor beyond two million volts, and it is impossible to charge Leyden jars to this potential, or to produce sparks in a laboratory of greater length than seven feet. To obtain the greatest manifestations of three million volts, it would be necessary to put the apparatus in an open field at least thirty feet from the ground, and remote from all other objects. Jars and circuits charged to this high voltage emit a luminous discharge to the floor of the room and to the brick walls, and indicate by this inductive discharge the presence of steam pipes twenty feet distant. The air breaks down quickly under this powerful electric stress, and, indeed, acts like a rarified gas.

Nevertheless discharges of electricity six and seven feet long are of interest, especially to many of you who are citizens of Boston, where Benjamin Franklin was born. These discharges closely resemble lightning, and one can reproduce all the photographic effects obtained by students of this astounding natural phenomenon. I have discovered the interesting fact that these long sparks are oscillatory.

The method of proof is this: I connected the condensers which were used in series to produce the high potential of three million volts, in multiple with a known self-induction. The discharge was then photographed. Here is one of the results: The distance between these bead-like figures from centre to centre represents one five-thousandth of a second (Fig 1). When the condensers are connected in series through the same self-induction the discharge still remains oscillatory, but of a much higher period; we are sure of this fact from Lord Kelvin's discussion of the limits of oscillatory action. You will perceive from Fig. 1 that I have been able, by means of the large battery and the large condenser, to photograph comparatively slow oscillations. I have lately succeeded in obtaining photographs of oscillations eight hundred a second; and experiments on the permeability of iron wire with powerful discharges with such low periods are now in progress.

That most discharges of lightning are to-and-fro, or oscillatory, I feel sure, and I have outlined my method of proof; but this was hardly necessary, for the photographs of the long sparks show on mere inspection the to-and-fro motion, for on the line of discharge forks can be observed pointing in opposite directions, showing that the discharge changed from positive to negative. These forks, or branching discharges, have an interesting peculiarity, which was brought out in the following manner. A sheet of plate glass about five feet square was placed between the terminals of the high potential apparatus, and a minute hole was bored in the middle of this plate.

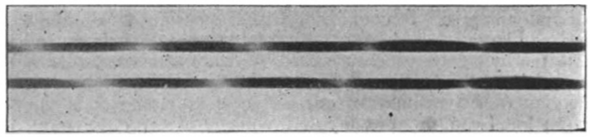

FIG. 1.

This hole could be made very small by plugging the orifice with paraffin, and making needle-holes in the paraffin. When the spark terminals were opposite the hole, each a foot and a-half from it, the spark sought the hole. A photograph of the spark (Fig. 2) shows an apparent breadth of spark much greater than the diameter of the hole; indeed, the minute size of the latter cannot be reproduced on the negative; while the spark seems to the eye to be an eighth of an inch in thickness, and actually measures about a millimetre in diameter on the negative. The reason of this phenomenon, I believe, is that only a portion of the discharge passes through the hole. This can be shown in the following manner. The terminals were not placed opposite the hole, but to one side of it, about a foot from it, and about half a foot from the glass. The discharge then jumped to the glass (Fig. 3), and pursued a devious way to the hole. When the hole was completely filled with paraffin the spark still jumped to the glass, apparently piercing a hole through it; but this was impossible, for the thickness prevented this. The discharge was continued evidently by an inductive action. I next restored the orifice, and, keeping the spark terminals in the last position referred to, I hung a large sheet of paraffined paper

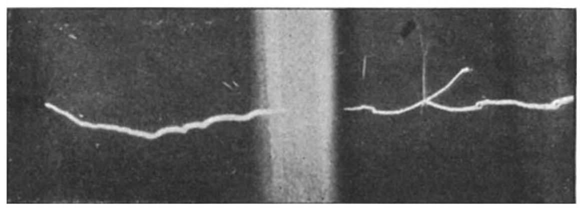

FIG. 2.

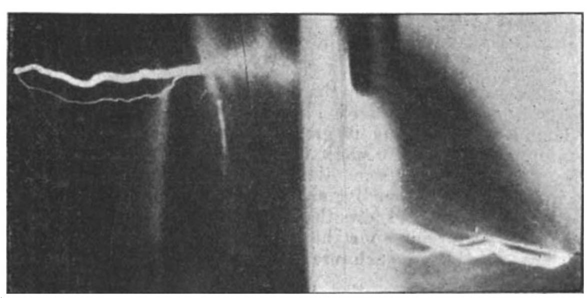

FIG. 3

[1] Paper read by Prof. John Trowbridge at a meeting of the American Academy of Arts and Sciences, held in the Jefferson Physical Laboratory, Harvard University, Cambridge, U.S.

on the glass, and a photograph of the spark was taken. It was found that an explosion occurred at each change in direction of the spark, or at each fork in it. The two effects are shown in Fig. 4 and Fig. 5; and you will see that even the sinuosities are reproduced by a rent in the paper. In the case of a thunderstorm, may not the peculiar rolling of the thunder be due to the successive explosions along the path of a single discharge some hundreds of feet apart?

But I will not dwell longer upon the fascinating study of lightning in a laboratory; for I wish to call your attention to larger fields of inquiry which the possession of this great battery opens. One of the most promising is that of spectrum analysis. In connection with the battery I have three hundred glass plate condensers, one-eighth of an inch thick, and about ten by eighteen inches coated surface; this condenser is charged in multiple to a potential of twenty thousand volts. The glass of the thickness of one-eighth of an inch stands this stress; but I can not use my full voltage of forty thousand, for the glass plates are immediately pierced. To utilise this voltage it will be necessary to employ plates a quarter of an inch in thickness. This is an interesting proof of the large

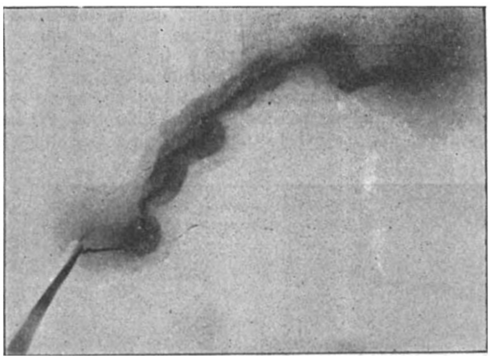

FIG. 4.

FIG 5.

surface density furnished by the battery. The noise of the discharge from this condenser is like the report of a pistol.

Here is an example of its great heating effect. An iron wire was stretched across the spark terminals. This was deflagrated (Fig. 6), while at the same time a spark passed between the terminals. The surrounding air was filled with the scintillating sparks of iron. This shows that it is not impossible that sparks may be formed inside a metallic cage or enclosure; for we can conceive of such an enclosure as a multiple circuit around a spark gap.

By means of the discharge of these condensers charged to a difference of potential of forty thousand volts, I can produce probably the highest degree of instantaneous temperature which has been reached. I have been obtaining instantaneous photographs of the spectra of gases and of the vapour of metals. One discharge, with a Browning direct vision spectroscope, will give a photograph of the spectra of hydrogen, and ten or twelve discharges are sufficient when a short focus grating is employed with a fairly fine slit. I find it desirable to use a peculiar end-on tube for the study of hydrogen. It is of the nature of a Crookes' tube, one end being blown into a very thin bulb; this tube can be heated to a very high temperature during the process of exhaustion to drive out the water vapour.

I have thus submitted hydrogen to a higher temperature than it has been possible to reach before, and the study of the spectra promises to have a bearing on stellar spectra. The advantage of an intense source of light, and consequently of a short time of exposure, is very great; for a large amount of fog is thus escaped, and faint lines come out which escape observation by the comparatively long exposures hitherto necessary.

There is another direction in which this battery can be used, which promises to be of importance in surgery. It furnishes a new source of the X-rays.

The greatest need in the scientific study, and also in the employment of the X-rays in surgery, is a steady source of them. All the methods now in use give a light which is far from constant; the electrical impulses which produce the rays are unequal in strength, and even when they are equal they are generally alternating in character. This to-and-fro action tends to produce a blurring of the shadows, for fluctuating electrical impulses sent through an X-ray tube are apt to give a shifting radiant point.

The ideal method of producing the rays is by the employment of a large storage battery, and I have been working toward this much-desired end during the past two years.

Traces of the X-rays can be obtained with a steady current at a voltage of five thousand; and they are strongly produced at twenty thousand. When forty thousand volts are used with a steady current, the exhibition of rays is surprising; a fluorescent screen is lighted with extreme brilliancy, and marvellous shadows of the bones of the hand are obtained. A steady current is undoubtedly the ideal current for the production of the

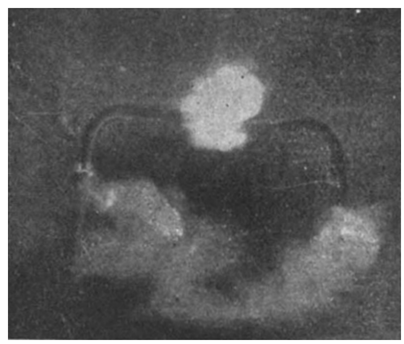

FIG. 6.

X-rays; for the radiant point of the rays does not fluctuate, and there is no to-and-fro or oscillatory motion which tends to produce what may be called X-rays ghosts. It is well known that these ghosts are often puzzling to the surgeon.

In my experiments I was surprised at the small amount of current necessary with a voltage of forty thousand to produce a strong development of the X-rays. The use of ten milliamperes was dangerous to the tube; the anode grew white hot, and the Crookes' tube resembled an enclosed arc lamp. It was interesting also to notice that the usual fluorescence ceased to be noticeable; and although the tube was of a milky white hue, the X-rays were extraordinarily brilliant. In my first experiments the fall of resistance in the tube was so rapid that the anti-kathode was melted. In the case of all the tubes with which I have experimented, the fall in resistance advances very rapidly with the degree of reddening of the anti-kathode. When this becomes red, or when a red spot appears on it, the difference of potential between the terminals of the tube does not in general exceed twenty thousand volts.

It would seem therefore uneconomical to continue the use of a high potential machine when this critical point is reached. At this point, moreover, the rays seem to be given off most vigorously, and at this stage a quantity machine giving a comparatively small voltage could be substituted to advantage for a coil or other apparatus giving six to eight inch sparks. A large storage battery makes it possible to regulate the strength of the current which is at any moment exciting the tube. I accomplish this at present by means of a liquid resistance, which enables me to graduate the strength of the current to any extent. This advantage is a very great one, and is not possessed by any other method. It seems possible, by carefully regulating the strength of the current and the voltage, to obtain photographs of the tendons, and possibly the muscles; for the photographs which I have already obtained show great contrasts, and there are indications of muscular layers and tendons. The contrast between the bones and the flesh is extraordinary, much greater than in the X-ray pictures usually obtained by the Rhumkorf coil.

The investigator, by means of the liquid resistance, can keep the tube at the same point of excitation. For the scientific study of the X-rays nothing seems better adapted than this large battery plant which I have had constructed, and it is not impossible that a smaller plant of the same number of cells, but with less capacity, may be desirable for large hospitals.

The first step in an investigation of the X-rays is to obtain a steady source of these rays: one of the essentials for the accomplishment of this is a steady current which can be regulated. This, I believe, I have secured. The next step will be the proper control of the amount of gas in the tube. At one time I believed that an oscillatory discharge was necessary for the strongest manifestation of the rays. My experiments, however, with a steady current have shown me that an oscillatory discharge is not essential; such a discharge could not take place through the large resistance which I used—4,000,000 ohms. Such are some of the results which can be obtained by the use of this large battery.

THE CRUISE AND DEEP-SEA EXPLORATION OF THE "SIBOGA" IN THE INDIAN ARCHIPELAGO.

THE annual summer meeting of the Netherlands Zoological Society, which was held in Amsterdam on July 1, was of more than usual interest on account of the fact that it was attended by all the members of the scientific staff of the *Siboga* expedition, who returned only a few weeks before from their one year's cruise in the different basins of the Indian Archipelago, during which they covered a distance of about 12,000 sea miles, *i.e.* about half the circumference of the globe. The track, as indicated on the accompanying Fig. 1, commenced at Soerabaja on March 7, 1899; it ended in the same port on February 27, 1900. The vessel, which is a cruiser belonging to the Dutch Royal Navy, was on its first trip, and before its departure was specially fitted up for the work of the cruise, both with a sounding apparatus of Le Blanc and of Lucas, with some 20 kilometres of wire rope for dredging purposes, and with all modern appliances for pelagic fishing, for plankton collection and for deep-sea work (a "sondeur à clef" of the Prince of Monaco, apparatus for obtaining sea-water from given depths according to Petterson and Sigsbee, Hensen's nets, &c.)

It may here be mentioned that very thorough experiments were made with Mr. G. H. Fowler's net, which is specially intended for plankton from given depths, and which can be opened and shut at will at any moment. About this net, which is of very recent invention, and which has as yet only been used by Mr. Fowler himself, and perhaps on board the *Valdivia*, the members of the *Siboga* expedition are very enthusiastic. It is most trustworthy in its results and fruitful in its catches.

The leader of the *Siboga* expedition, Prof. Max Weber of Amsterdam, well-known by his former expeditions to the East Indies, to the far north and to South Africa, was accompanied by Madame Weber-van Bosse, herself an accomplished naturalist, who made a very complete collection of Algæ during the cruise, and who settled three very important points as a result of the observations made, viz.: (1) the presence in unexpected quantities of calcareous Algæ (Lithothamnion) in the Archipelago, so that they build up reefs of considerable dimensions, in depths of 3 to 40 metres, in one case even at 120 metres. Different circumstances of level, current, &c., must co-operate to render the occurrence of Lithothamnion in such quantities possible: the expedition found them realised in at least thirty different localities, and henceforth the possible contribution of Lithothamnion-remains to the formation of the earth's crust will in many cases have to be reconsidered by the geologists. (2) The presence of a minute vegetal organism about which of late years English and German naturalists have considerably differed in opinion: the Coccosphære. Neither the members of the German Plankton nor those of the *Valdivia* expedition have succeeded in satisfying themselves that these miniature spheres with adherent discs of lime, already known in the Cretaceous

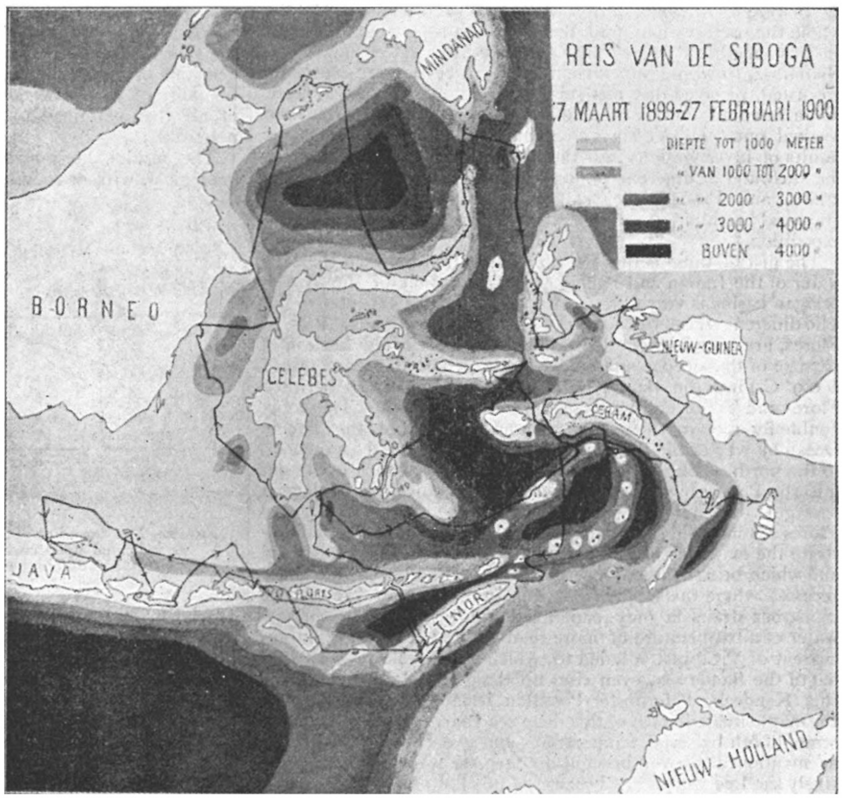

FIG. 1.—Track of the *Siboga*.

period and everywhere present on the bottom of the sea, are organisms and not inorganic concretions or sediments. Mme. Weber has now succeeded in demonstrating the truth of the contrary, and has found this very lowly organised alga in great abundance, and entirely agrees with Mr. George Murray's statements concerning the alga-nature of the coccospheres; she has even found in this alga green chromatophores, and has seen phases of division of the spheres; (3) the presence of shell- and rock-perforating algæ, a group hitherto neglected in the tropics, of which she has brought home a great number.

The zoological collections of the *Siboga* are very extensive, both those collected on the coral-reefs and from the very different depths. Deep-sea animals were met with at depths of about 150 fathoms, where they would hardly have been expected, but where their presence is explained by certain hydrographical circumstances to be mentioned later. Porifera, and among them the most diverse Hexactinellids, were exceedingly numerous. East of the Aru Islands, gigantic